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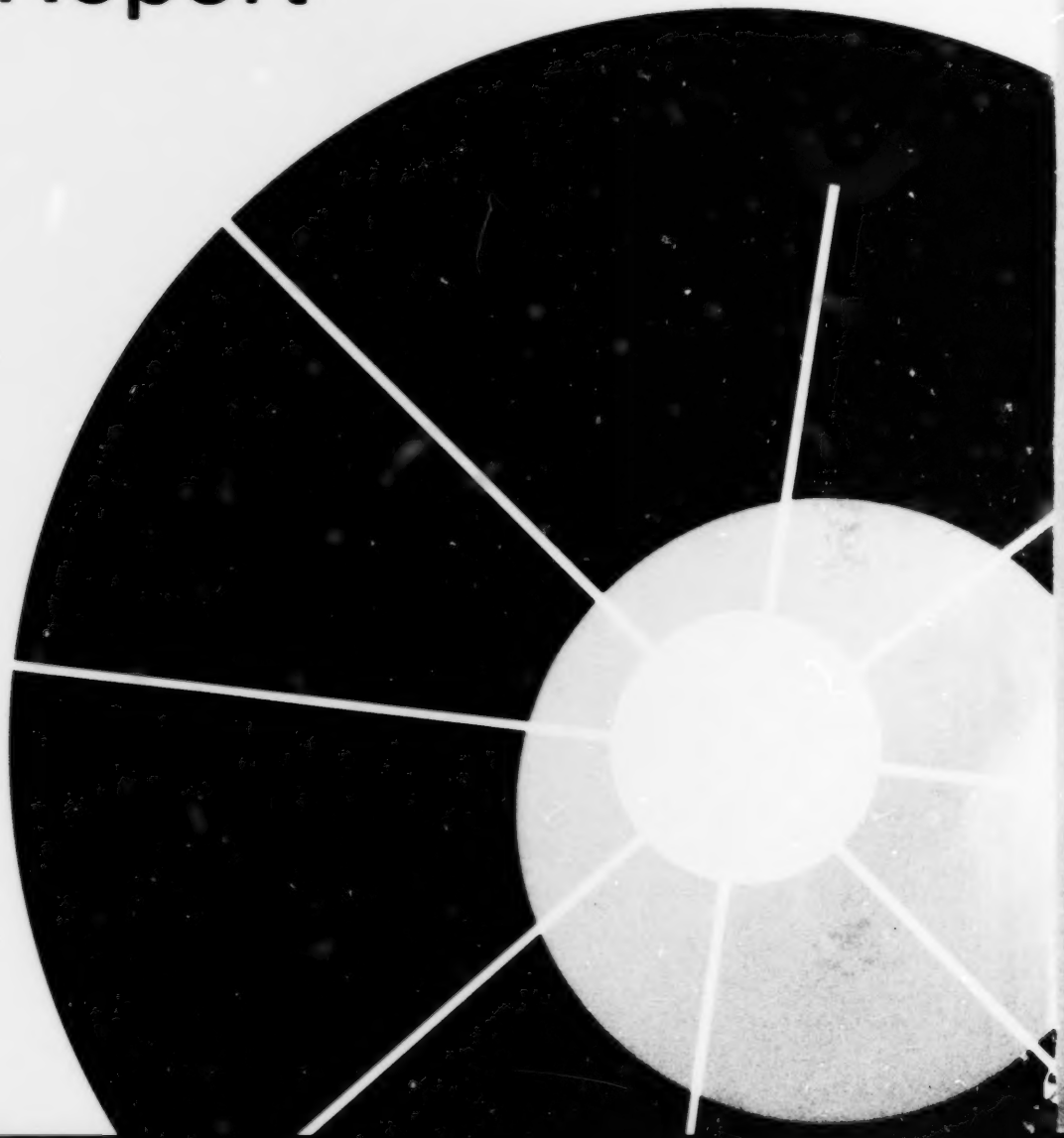
Canada - Saskatchewan Renewables — Conservation Demonstration Program

Final Report



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CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

— To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;

— To create employment in new or existing industries;

— To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Government of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

However, neither the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, nor the Government of Canada as represented by Energy, Mines and Resources Canada, accept liability for any errors, omissions, or inaccuracies that may; be included in or derived from this report, nor do they assume any liability with respect to the use of, or actions resulting from the use of, any information contained in this report.

The Yorkton Conservahome

The Retrofit and Rehabilitation of a 1963 Platform-Framed Single-Storey House with Full Concrete Basement

Final Technical Report
on a Renewables-Conservation Demonstration Program Project

Conducted By

The Saskatchewan Research Council

And Supported By

Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada

Project Leaders: Dave Eyre and Dave Jennings

Miscellaneous
Report FP-18

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FIGURES

FIGURE 1. Plans and sectional view	4 and 5

This report gives details of the retrofit and rehabilitation work conducted on a house in Yorkton, Saskatchewan, as part of the Conservahome Project. This project involved the retrofit and rehabilitation of six houses of various ages and styles, and was funded by CREDA: the federal-provincial Conservation and Renewable Energy Demonstration Agreement. For further details of this project the reader is referred tp the Overview Report, which is the first in this series of reports on the project.

The city of Yorkton is located in south east Saskatchewan close to the Manitoba border. It was chosen for the Conservahome project on the basis of its fairly large population and its geographic location - both of which would add to the demonstrational value of the project.

The Yorkton Conservahome was the last of the six to be selected. The other five Conservahomes had been purchased and the retrofit strategies had been tentatively established. Therefore, when it came to selecting the Yorkton Conservahome it was hard to find a house that would complement the other five. Several attempts were made to select a suitable house over a period of about three months, and about 15 houses were rejected for one reason or another. For a while, the best candidate appeared to be a masonry house - single brick with a 38 mm stud frame interior - but on further inspection the structural details were found to be so unusual that the retrofit work would have had little application to other houses. Eventually, a 1963 house came up for sale and was purchased almost immediately for the project. It was not outstanding in any respect, but it offered a reasonable compromise of the various requirements for the project.

The Conservahome Project included three houses built after 1960. These were similar in the main structural details. For the purposes of demonstration it was decided to adopt different levels of retrofit on the three houses. Thus, a high-level retrofit was chosen for the Prince Albert House and a low-level retrofit was chosen for the Moose Jaw house. The Yorkton Conservahome was selected for the demonstration of medium-level retrofit.

The Yorkton Conservahome is of interest for the following reasons:

- The basement walls were insulated by two different techniques: one involving a wood-frame construc- and the other involving the application of a rigid insulation system.

- Retrofit on the exterior house walls was limited to the sealing of air leakage points.

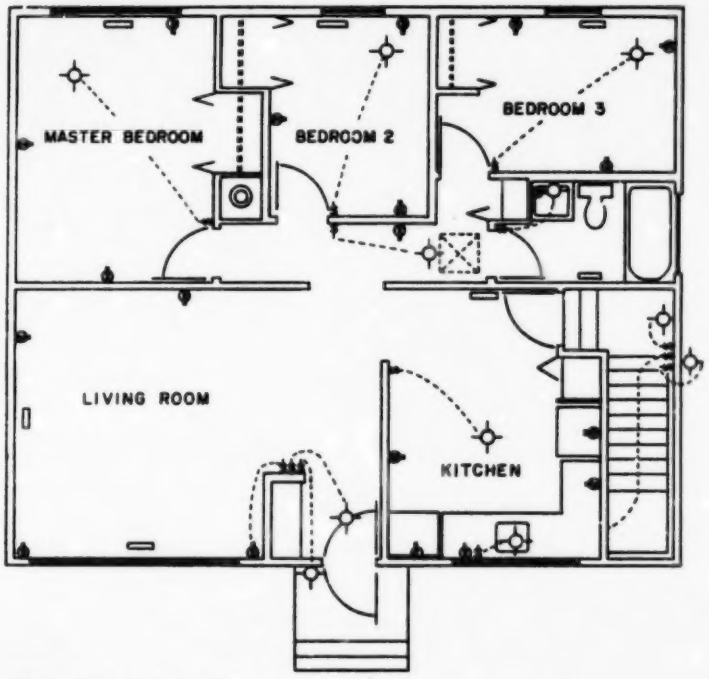
- Several different techniques were tried for upgrading the thermal performance of the windows.

The house is located at Lots 1 and 2, Block 14, Plan Z2171. The front of the house faces west on a north-south street. The house was built in 1963. Plans were not filed with the city building authorities, but it was discovered that the house design was a "standard" design that was still on file with the builder. Plans were obtained from the builder, thereby eliminating the problems of conducting detailed measurements and drawing up new plans.

The house is located in the north-east sector of Yorkton, on relatively high ground. The soil appeared to be non-expansive and the drainage appeared to be good. The basement was partially developed and in excellent condition. The main storey was in average-to-good condition on the interior and exterior, though there were extensive signs of condensation on window sills and on the drywall beneath. On further investigation it was concluded that the condensation was a consequence of occupancy patterns rather than an indication of structural defects. The attic and roof were in good condition, with typical insulation levels and a typical range of air leakage openings.

The plans and sectional view of the house are shown in figure 1 on the following two pages. These are taken directly from the builder's plans and may differ slightly from the as-built dimensions. The house is a single-storey platform frame structure on a full concrete basement, with a plan area of 88.3 m^2. It is essentially in its original form, but with extensive basement development and some do-it-yourself ventilation systems.

After the purchase of the house, two severe hail storms passed through the area and caused damage to the roof and part of the decorative exterior siding. This was repaired as part of the retrofit and rehabilitation work, though the costs of this were covered by hail insurance.



MAIN FLOOR PLAN

Figure 1. Plans and sectional View

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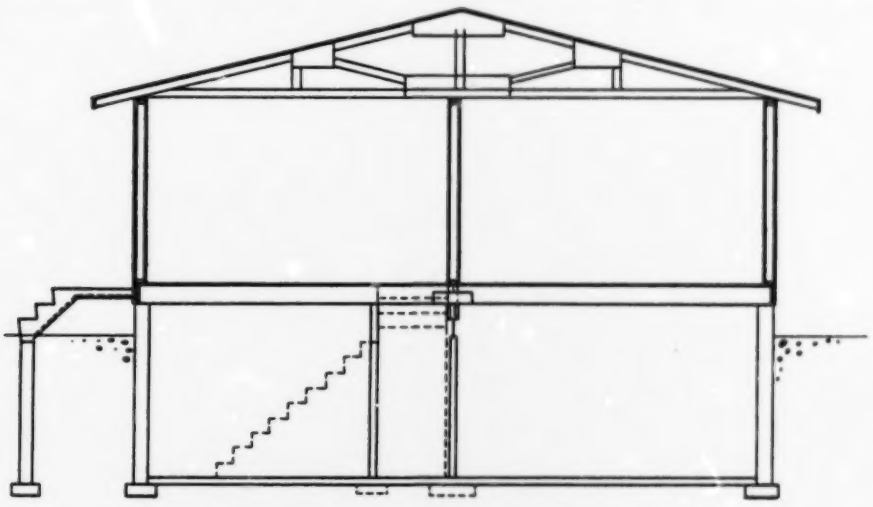
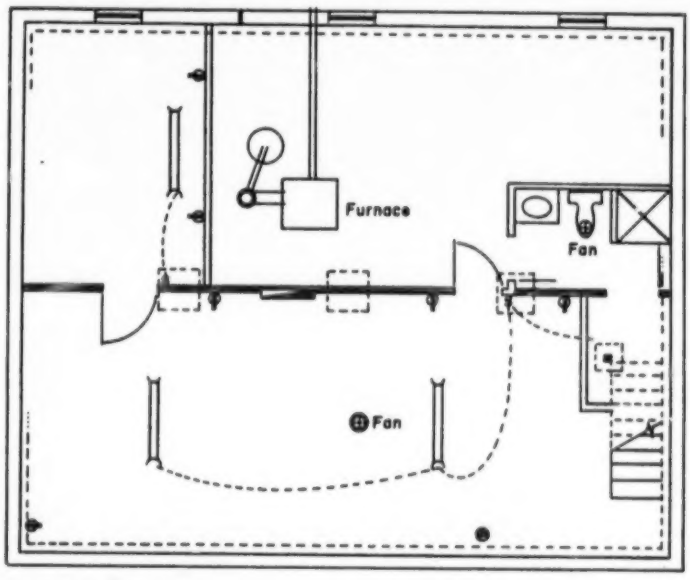
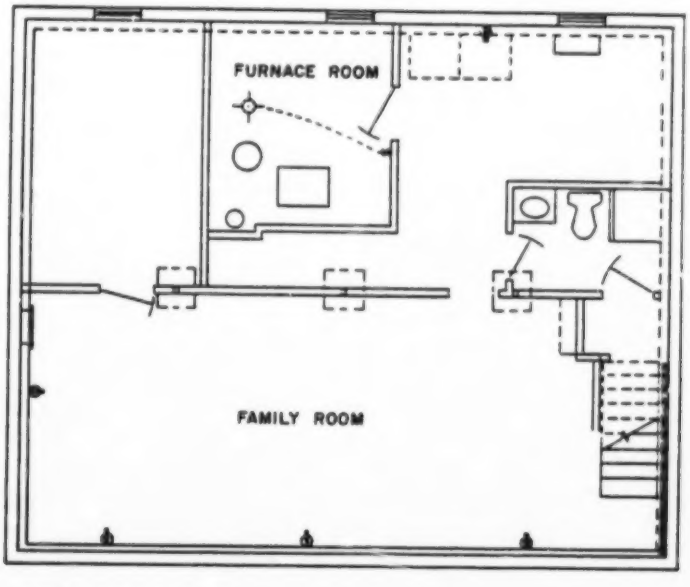


SECTIONAL VIEW LOOKING NORTH



BASEMENT PLAN

Figure 1. Continued



BASEMENT PLAN AFTER RETROFIT

The house had a natural gas forced-air furnace and a natural gas DHW heater. The measured thermal efficiency of the furnace was 73.8%. This is about 5% higher than is normally found in gas furnaces in Saskatchewan, and will be discussed later. The house was purchased after the occupants had left, and they could not be contacted to establish the average occupancy pattern. It is believed that the family consisted of 5 or 6 persons.

Natural gas and electricity bills were obtained from the Saskatchewan Power Corporation for the year beginning June 21, 1978. The rate of gas usage during the summer months was taken to represent the gas consumption of the DHW heater, and it was assumed that this same rate of usage applied throughout the year. This gave the following breakdown of annual gas consumption:

Space heating (natural gas)	4709 m^3
DHW heating (natural gas)	1614 m^3
Total annual gas consumption	6323 m^3

The annual heating degree-day figure for Yorkton is 6243 °C.d based on the thirty-year average, and was 6988 °C.d for the one-year period covered by the fuel bills. The period was therefore appreciably more severe than the average. The two heating degree-day figures were used to correct the space heating consumption to 'average' annual conditions, giving:

Space heat consumption, average year	4207 m^3

The total electrical consumption for the period was 5937 kWh, corresponding to an average of 16.3 kWh per day.

The DHW gas usage was about average for Saskatchewan and for a family of this presumed size. The electrical usage was significantly lower than average. For a family of this presumed size the average consumption is about 22 to 25 kWh per day. The space heating requirements of the house were calculated theoretically, using the known dimensions of the house and the estimated thermal resistances of the various parts of the house envelope. This gave:

Calculated annual space heat requirement 141 GJ

With a furnace efficiency of 73.8%, this corresponds to a space heating gas consumption of 5141 m^3, which is 22% higher than the figure 4207 m^3 derived from the fuel bills. The discrepancy is believed to be due to an error in the assumption that only the DHW heater used gas during the summer months. On further investigation it was found that the summer months (July and August 1978, and May and June 1979) were substantially colder than average (567 heating degree days as compared with a 30-year average of 433). It therefore appears likely that the gas furnace was operating at a moderatly low level during this four month period. This would tend to give a high estimate of DHW usage and would give a low figure for the derived space heating usage.

4.1 Assessment

The foundation walls and floor were in excellent condition, with no significant cracks and no evidence of alkaline attack. The builder must have used new plywood forms when pouring the basement walls; the walls surfaces were so smooth that, in some places, the owner had applied vinyl wallpaper directly to the concrete surface - and it was only after further investigation that it was discovered that the concrete had not been covered with drywall. The wallpaper had good adhesion to the concrete, indicating that there was no significant moisture seepage through the concrete. This suggested that the concrete was in good condition and the drainage system was effective.

The basement had been developed in various ways. A 38 mm x 89 mm wood frame partition wall had been installed over the full length of the basement, under the main support beam (see figure 1). This divided the basement area into two halves. One half was taken up entirely by a family room, and the other half contained a bedroom, a well-finished bathroom and an undeveloped furnace/laundry area.

The basement walls were covered by development at only three places:

- The north wall of the family room had been covered with a 38 mm x 38 mm stud frame, finished with wood panelling. It is believed that this work was mainly 'cosmetic', ie. designed to cover the electrical service panel and associated wiring.

- The area under the stairs had been developed as a storage cupboard, but without any covering over the foundation wall.

- The bathroom has a 38 mm x 89 mm stud frame. Where this joined onto the south wall of the foundation wall, the frame had been insulated with glass fibre batt (RSI 2.11) and had been fitted with a vapour barrier of 0.05 mm polyethylene.

The family room ceiling was covered with a suspended ceiling system, containing fluorescent lighting and a ceiling exhaust fan that was ducted to the east wall and vented outside. The bedroom ceiling was finished with strapping and ceiling tile.

Access to the top of the foundation wall was generally good. There was direct access in the furnace/laundry room, and good access in the family room merely by removing the suspended ceiling panels. The tops of the foundation walls in the bedroom were less accessible. In this room it would be necessary to remove and destroy some of the ceiling tiles. The associated cost penalty was small.

4.2 Retrofit Alternatives

It was planned to demonstrate a medium-level retrofit on the Yorkton Conservahome. It would have been out of the question to add more insulation to the walls around the main storey - all of the alterantives would have been too costly. Therefore, it was logical to focus on the attic and the basement. The basement walls were practically undeveloped, and the obvious course was to consider insulating these walls.

Before deciding how to insulate a basement wall, it is first necessary to consider their condition. If the walls are badly cracked or display large areas of alkaline attack, then these problems may be caused by the surrounding soil, inadequate drainage, low quality concrete or combinations of these factors. Where such faults exist, it is inadvisable to insulate the basement without first conducting remedial work. The grouting of cracks and the repair of defective concrete areas are not remedies in the true sense of the word - since they are directed at the symptoms of failure rather than at the causes. It is therefore likely that, within a few years, the grouted cracks will open up once more, and the areas of alkaline attack will spread, thereby creating a risk of structural damage to the insulation work. Where a basement is in poor condition, there are two basic options: either leave it uninsulated or do something to correct the causes of failure.

The causes of failure are usually to be found outside the basement wall: ie: poor drainage, expansive soil, frost heave, high water table, etc. Therefore, excavation is necessary, followed by repair of the drainage system, backfill with a non-reactive gravel and, as a final step, repair of the basement walls from outside. This creates the opportunity to add insulation to the exterior of the basement wall. This approach is generally preferable, since the insulation protects the concrete from extreme temperature cycling.

If the basement wall is in good condition, and has been in place for many years, this can be taken as an indication that there are no real structural problems. However, before proceeding with insulation work, one has to consider the possibility that this work may cause problems. When a basement wall is insulated, the flow of heat from the house to the surrounding soil is reduced. Consequently, the soil around the basement will experience greater annual temperature swings. The winter soil temperature will be significantly lower than before retrofit. The potential for frost heave and other interactions will be stronger. Also, the depth of frost penetration will increase, and may reach the footings, where it might affect the drainage system. There are no firm rules for assessing the likelihood of such effects, and the assessor may be called upon to make some difficult - and sometimes questionable - decisions.

In this instance, the basement of the Yorkton house was sufficiently sound to allay doubts about long-term retrofit effects. It was therefore decided to insulate the basement on the inside, because it offered better access, had better potential for demonstration, and was more cost-effective than the exterior approach. In determining the cost effectiveness, it should be noted that the interior approach produces a finished and developed basement, which adds to the value of the house.

For the purposes of demonstration, and to provide comparative cost information, it was decided to insulate the basement walls by two different methods.

The first method would consist of the installation of glass fibre batt in a wood frame. The second would consist of rigid insulation applied directly to the foundation wall.

4.3 Factors affecting the choice

When insulating a foundation wall, some thought has to be given to the area of coverage. Does one insulate the whole wall or leave an uninsulated section at the foot of the wall? The latter course has two advantages: first, it allows some heat to escape from the house to the footings, and inhibits frost action around the weeping tile system; secondly, insulation becomes less cost effective as one goes further down the foundation wall - because of the increased insulation effect of the soil. This issue was discussed in the report on the Prince Albert Conservahome, where it was decided that there might be some risk of frost effects at the footings if the foundation wall was insulated to full height. At Yorkton, however, the footings were about 2290 mm below grade, in well drained soil, and the risk of frost damage at the footings was felt to be negligible. It was therefore decided to insulate the foundation walls to full height.

When insulating a foundation wall, basement stairs may present a problem when they run down the side of the wall. For a thorough insulation job, the stairs have to be removed to give full access to the wall. Then, when the stairs are replaced, they are out of line as a result of the increased wall thickness. This is tolerable if the added insulation layer is not too thick. In this instance, with two types of insulation being applied, it was obviously preferable to use the rigid insulation technique in the stairwell, since the added thickness was about 63 mm.

It was proposed to supplement the insulation work by sealing the air leakage points in the foundation wall. The main air leakage openings are found at the top of the wall, where the wood frame is joined to the concrete. This area constitutes a major source of air leakage in some houses, particularly where the sub-floor consists of shiplap material.

Shiplap floors are usually laid diagonally across the floor joists , and have lapped joints running under the sill plates of the walls. These joints act as air leakage channels. However, in houses of post-1960 construction it is more common to find plywood sub-floors. Because of the continuity of the plywood surface it is usually easier to achieve higher levels of airtightness sealing at the top of the foundation wall.

The amount of air leakage depends on the detailed construction at this point. If the walls are finished with shiplap sheathing and customary wood siding, these have extensive leakage openings which help to promote air leakage at the top of the foundation wall. But if the walls are finished with plywood sheathing and stucco, as in this instance, the rate of air leakage is somewhat reduced.

The sealing technique is dictated by the details of construction at the top of the foundation wall. In Saskatchewan housing it has been customary to set the joists into the concrete at the time of pouring. Good practice requires that at least two-thirds of the joist depth is set into the concrete. The gap between the concrete and the sub-floor may therefore display a considerable variation from house to house. In some it may be just a crack; in others it may be as much as 75 mm to 100 mm. If the gap is just a crack, it may be sealed by running a bead of caulk along the crack. If the gap is large, there is usually enough room to work caulk into all the structural cracks. However, if the gap is of intermediate size, about 50 mm, neither of the above techniques are effective - the gap is too wide to be sealed by caulk and too narrow to allow access for caulking at the back of the foundation wall. The best option, in these circumstances, is to try to block the 50 mm gap in some way. One technique is to compress glass fibre into the gap, and this is commonly used by homeowners and some builders. Another technique, developed recently in Ontario, is to fill the gap with urethane foam. In each case it should be noted that the intention is not to insulate the gap, but to eliminate air leaks and moisture movement.

These sealing techniques are acceptable when it is not proposed to conduct any extensive retrofit on the basement walls. However, in this case, it was proposed to insulate the walls and install an air-tight vapour barrier. In the Yorkton house, the gap between the top of the foundation wall and the sub-floor was about 38 mm wide. Some attempt had already been made to seal the gap with packed glass fibre batt. This was a problem, in a sense, because it constituted a vapour retarder, which would be on the wrong side of the dewpoint once the insulation was installed. It would therefore promote condensation unless a new and more effective air-vapour barrier were to be installed on the warm side of the insulation.

4.4 Details of the upgrading work *

Preparation:

Carpeting and other loose articles were removed from the basement area to give clear access.

In the family room, the suspended ceiling panels were removed to give access to the foundation wall, and the suspended ceiling frames along the wall were also removed. This equipment was stored for re-installation.

Sections of the ceiling tile in the bedroom were removed to give access to the tops of the foundation wall.

The 38 mm x 38 mm stud frame along the north wall was dismantled and the panelling was stored for re-installation. Sections of panel were removed from the two partition walls, where they butted to the north and east foundation walls. The objective was to allow the insulation and air-vapour barrier to be carried across the ends of these partitions.

The laundry plumbing system against the east wall was dismantled. The existing stand-pipe was modified with two 45° elbows so that it would stand clear of the new insulated wall.

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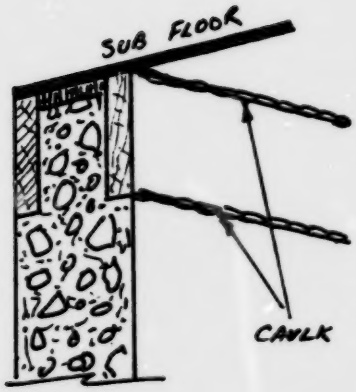
* The detailed specifications of all the upgrading work are given in Appendix I, consisting of the Specifications from the contract documents.

Four vent systems passed through the foundation wall on the east side (these will be discussed in the section on ventilation). It was proposed to retain these vents but use them in a different way. The ducts were therefore disconnected and the vents were temporarily capped.

A light shelf construction had been installed against the basement stairs. This was dismantled and discarded. The stairs were removed to give access to the south wall.

All wallpaper was removed from the basement walls, which were then given a coating of bitumen-based moisture barrier, from the bottom of the walls to grade level.

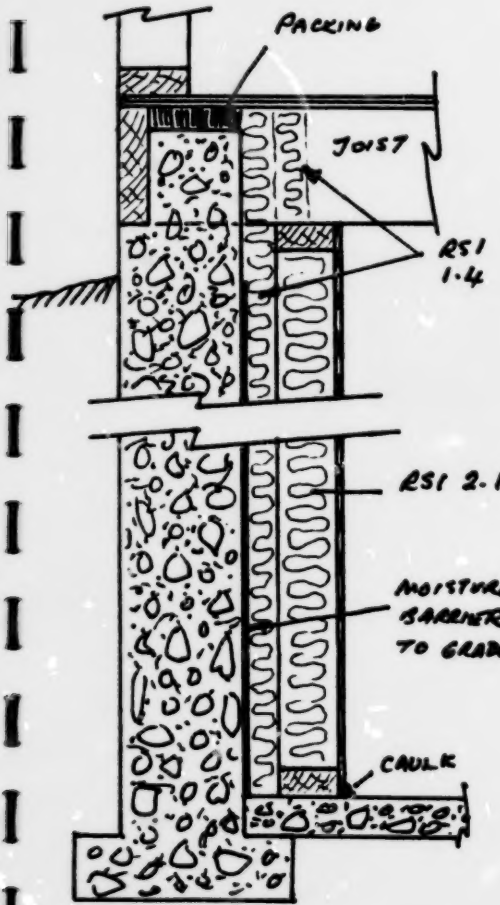
Sealing:



NORTH FOUNDATION WALL.

Bearing in mind the proposed quality of insulation and new air-vapour barrier, it was not strictly necessary to do anything about sealing the air leakage gaps at the top of the foundation walls. However, it was decided to conduct some minor sealing work in this area. Caulking was applied along the constructional joint between the header and the concrete - where the inner header ran along the top of the north foundation wall. With the benefits of hindsight it would have been better to leave this area uncaulked. With the proposed insulation and new air-vapour barrier, any moisture passing into the basement through the foundation wall would be virtually trapped between the foundation wall and the air-vapour barrier. It would have no way of escaping except through any gaps and openings at the top of the foundation wall. Therefore, the existing air leakage points would have reduced the risk of moisture build-up and should have been left untouched.

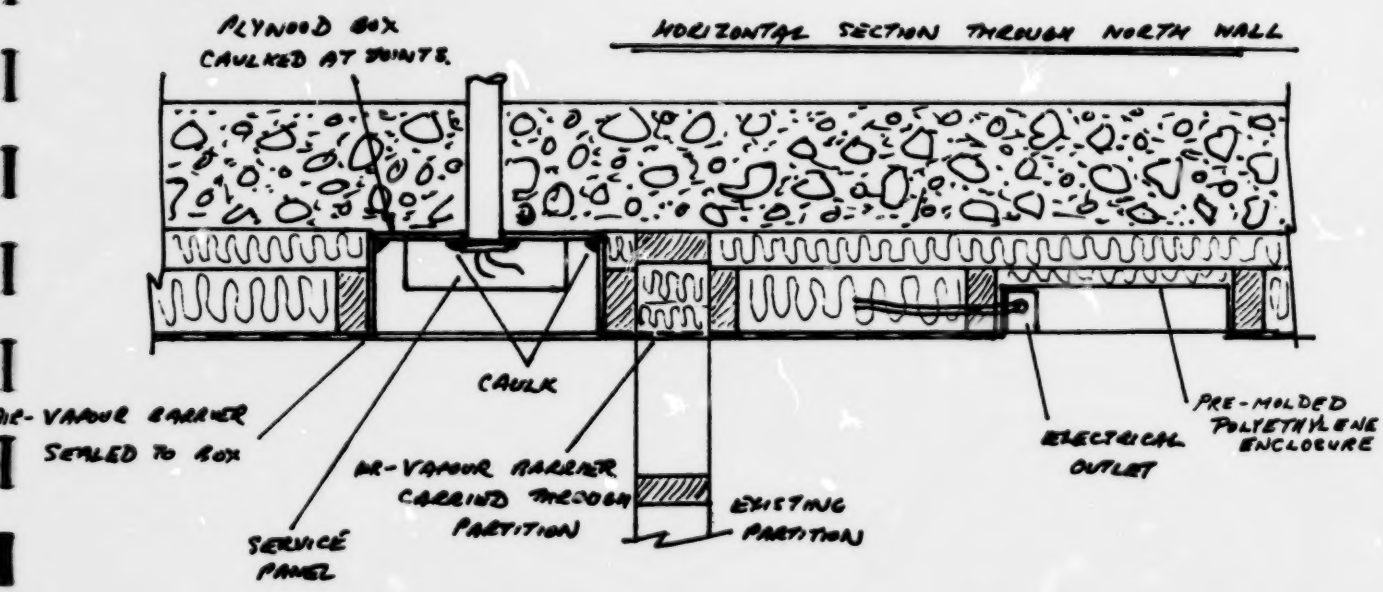
The gaps around the four vent pipes were caulked, where they passed through the foundation wall.

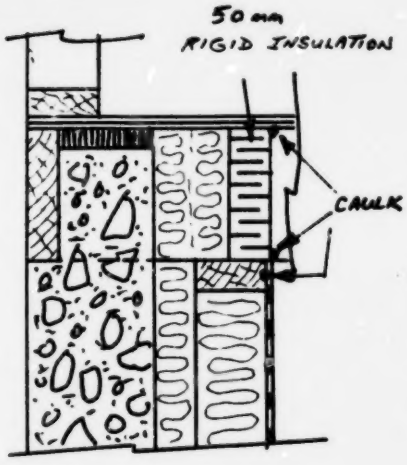


Glass fibre insulation:

A wood frame wall was constructed around the west and north foundation walls. This consisted of 38 mm x 89 mm studs on 600 mm centres, and was positioned with a clearance of about 65 mm from the foundation wall. Caulk was applied at the joint of the bottom plate and the concrete floor. A sealed plywood box was constructed around the service panel and inlet conduit.

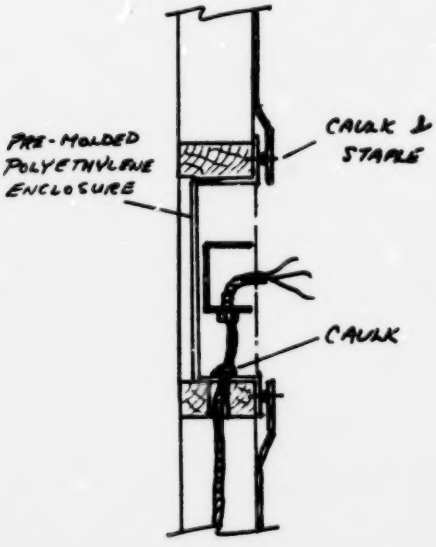
Glass fibre batt insulation, RSI 1.41, 63 mm thick, was installed behind the wood frame to give complete coverage of the foundation wall - right up to the sub floor. The practice of putting insulation behind the studs reduces heat losses due to thermal bridging through the studs. Electrical outlets were installed in the frame, and were provided with pre-molded polyethylene enclosures to give a continuity of the air-vapour barrier around the back of the outlets. Caulking was applied around the electrical cables where they passed through the pre-molded polyethylene enclosures. A second layer of glass fibre batt insulation, RSI 2.1, 89 mm thick, was then installed in the usual way between the studs. A second layer of 63 mm batt insulation was installed above the top plate of the stud frame. The sketches on this page show various details of the construction, including the air-vapour barrier, which was to be installed later.





Air-vapour barrier and sealing:

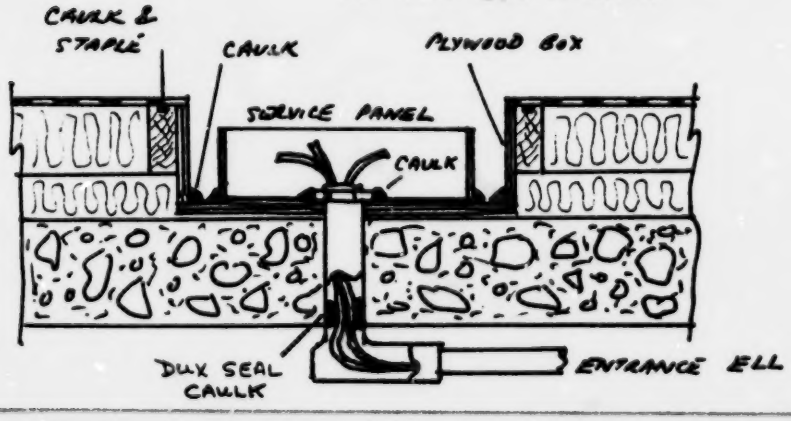
The new framed wall was covered with a continuous sheet of 0.150 mm polyethylene. This was caulked and stapled to the top and bottom plates of the wood frame to make a good seal around the edges. The joist space, above the top plate of the wood frame, required a special air-vapour barrier technique. One way would have been to caulk and staple a section of polyethylene sheet between each pair of joists, but this demands a great deal of time and care, and is therefore costly. It was therefore decided to seal these spaces by inserting tightly-fitting pieces of extruded polystyrene rigid insulation (50 mm thick, RSI 1.76). Extruded polystyrene has a low permeability to moisture movement and therefore acts like a vapour barrier. The extruded polystyrene sections were fitted tightly between the joists and caulked around the edges to make a good seal. Caulking was also applied where the rigid insulation butted to the top plate, to give a good seal between the rigid insulation and the polyethylene on the stud frame.



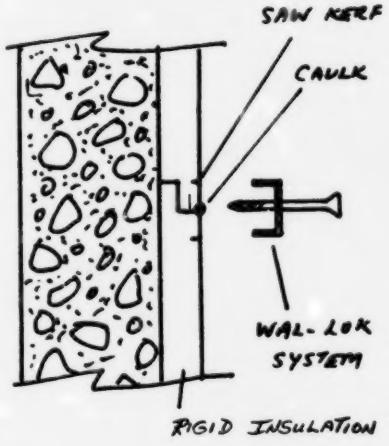
Sealant was applied around the flange of the pre-molded polyethylene enclosures before the main air-vapour barrier was installed around electrical receptacles. The air-vapour barrier was then pressed against this seal and stapled to make a tight joint.

The air-vapour barrier was trimmed around the edges of the plywood box, built around the service panel. It was then caulked and stapled to the front of the box to make a tight seal.

Working from the outside of the house, Dux Seal was worked into the service conduit, around the electrical cables, to make an airtight seal. Dux Seal is a proprietory caulking material approved for this type of work.

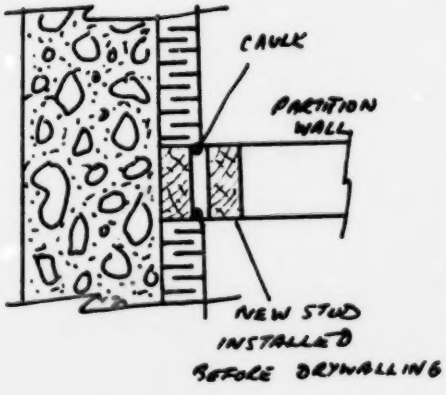


Rigid insulation:



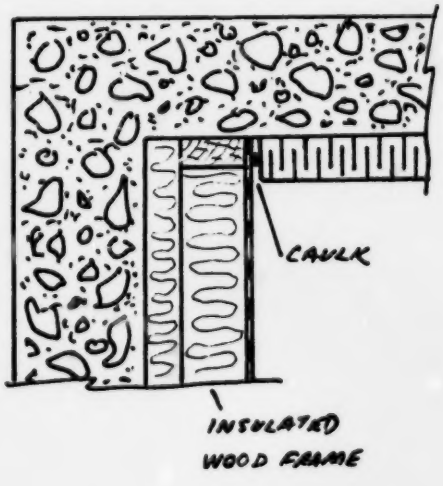
The east and south walls were insulated with 50 mm extruded polystyrene insulation (RSI 1.76), attached by a proprietory system known as Wal-Lok. In this system a shallow U-shaped metal channel is set into saw kerfs cut in the rigid insulation, so that it bridges the joint. A special drill attachment is used to drill through the channel and into the foundation wall. A special type of screw is then used to secure the channel. The rigid insulation panels had half-lapped edges, and were laid horizontally. The joints were caulked, so that the rigid insulation would act as an air-vapour barrier, thereby eliminating the need for a polyethylene air-vapour barrier.

Tightly fitting pieces of rigid insulation were inserted between the joists and caulked to make a tight seal, as mentioned previously. Caulking was applied around the four vents on the east wall, where they passed through the rigid insulation.



Where the rigid insulation joined to the insulated wood frame, in the south-west and north-east corners of the basement, caulking was applied to make a tight seal between the rigid insulation and the air-vapour barrier. Caulking was also used to seal the rigid insulation at the partition wall, where it joined the east wall of the basement - and some attempt was made to seal the rigid insulation where it joined the bathroom wall framing.

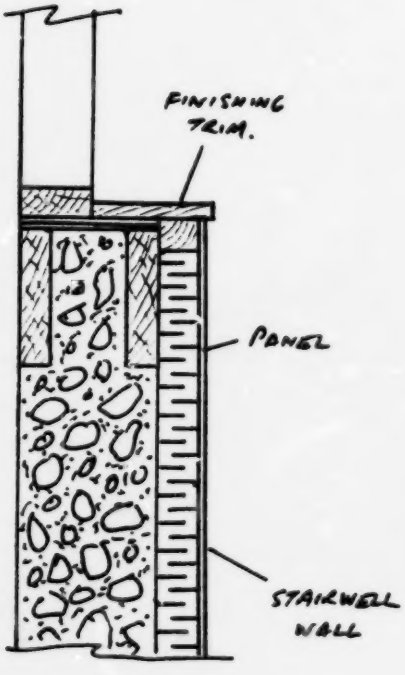
NORTH-EAST CORNER OF BASEMENT



Finishing off:

New studs were provided at the outer ends of the partition walls, to act as nailing strips for the partition wall panelling. Drywall was installed around the family room and the bedroom wall surfaces, including between floor joist spaces, as mechanical and fire protection. The basement stairs were installed and a new door, with trim, was fitted over the electrical service panel.

Drywall was attached over the rigid insulation on the east and south walls of the furnace/laundry room, as mechanical and fire protection. This is done with drywall screws, fixed into the metal Wal-Lok channel. New drywall was also installed over the exterior of the bathroom wood frame wall, in the furnace/laundry room. This was installed only after the various ducting and electrical changes had been made. All drywall was left unfinished, without taping or sanding.



A plywood panel was installed on the east wall, to provide a firm backing for the various laundry services. Electrical outlets were installed for the dryer and the washing machine. Hot and cold water supplies were installed for the washing machine. Electrical outlets were installed in the prepared boxes around the basement walls.

On completion of this work, one wood panel and one drywall panel were removed to allow demonstration of the structural details of the two methods of insulation.

A finishing trim was installed along the top of the foundation wall in the stairwell.

5.1 Assessment

The interior faces of the walls were in average condition, with normal signs of wear and tear. Small areas of deteriorated drywall were found under most windows, and were obviously the result of excessive condensation on the windows. The baseboards were of poor quality and had been fitted badly after the recent installation of carpet. Several lengths of unused baseboard had been stored in the basement, and could be used for upgrading the baseboards.

The walls showed the normal sources of air leakage - mainly at electrical outlets. Other leakage points were found where the existing vapour barrier was terminated around windows and doors, and also at the foot of the walls, where the gap under the sill plate was a source of air leakage. The kitchen sink was connected to a vent stack running inside the exterior wall. The connection from the sink to the stack was poorly sealed where it passed through the drywall.

The house was equipped with a milk chute, located close to the door on the south wall. This was a major source of air leakage.

From the outside of the house the walls appeared to be in fairly good condition. The majority of the wall area was covered with painted stucco, with the bottom 600 mm parged over the foundation wall. Around some of the windows, the exterior was finished with painted plywood panels, giving a continuation of the window line. On the north wall of the house, about half of the wall area was finished in vertical tongue-and-groove siding. The only significant defects on the house exterior were found at the corners, and near the doors, where the parge had cracked and broken away. This deterioration was not very extensive.

As far as could be ascertained, the walls were insulated with high density glass fibre batt, with an assumed thermal resistance of RSI 1.59. The vapour barrier was 0.05 mm polyethylene, installed in the usual way for a house of this age.

5.2 Retrofit Alternatives

For a house in this condition, with fairly good walls and a marginally tolerable level of insulation, it is difficult to justify a major re-insulation retrofit of the walls. Each of the three main options - interior addition, exterior addition and re-insulation of the wall cavity - is very costly, and would merit consideration only if the walls required structural changes for one reason or another. In this case the walls were in acceptably good condition, and a re-insulation retrofit would not have been advisable.

This decision was supported by the demonstrational objectives of this house, which were centred on a medium-level retrofit.

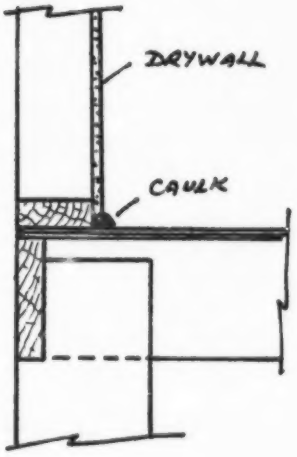
When the re-insulation options are ruled out, the only remaining option is to seal the exterior walls and reduce their existing heat losses due to air leakage.

5.3 Factors affecting the choice

Most of the air leakage points were accessible without any significant structural work. The only exceptions to this were the air leakage gaps around windows and doors, and under the sill plate of the exterior wall. To seal these points, it is necessary to remove door trim, window trim and baseboards. The baseboards were badly installed anyway, and therefore some small cost benefits could be gained by combining baseboard rehabilitation with sealing at the sill plates.

There were two ways of dealing with the milk chute: either remove it and finish the wall to match, or upgrade it. The milk chute was a significant source of air leakage, and is not uncommon in houses of this vintage. Therefore, it was decided to retain the milk chute and demonstrate a technique for reducing its air leakage rate.

5.4 Details of upgrading work



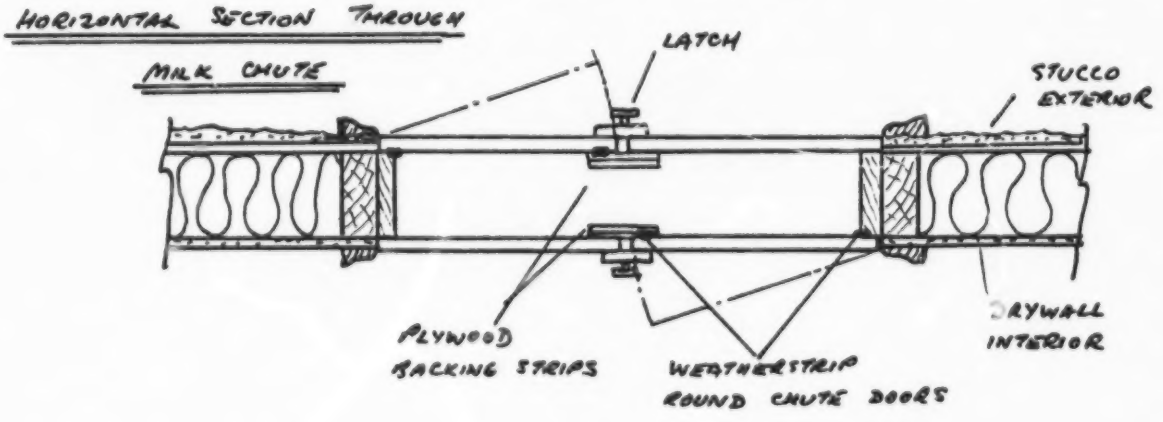
Baseboards were removed and caulk was applied to make an airtight seal at the gap between the sub-floor and the bottom plate of the exterior wall. Carpets were re-fitted and new baseboard was installed.

The cover plates were removed from electrical outlets in exterior walls, fitted with "Draft Ender" gaskets and replaced. Safety plastic inserts were fitted in the outlet terminals to reduce air leakage at these points.

The trim was removed from windows and exterior doors. This revealed a gap between the drywall and the frames of the doors and windows. Where the gap was narrow (less than 3 mm) it was sealed with caulk. Where the gap was larger than 3 mm a strip of standard duct tape was installed over the gap. The trim was then replaced.

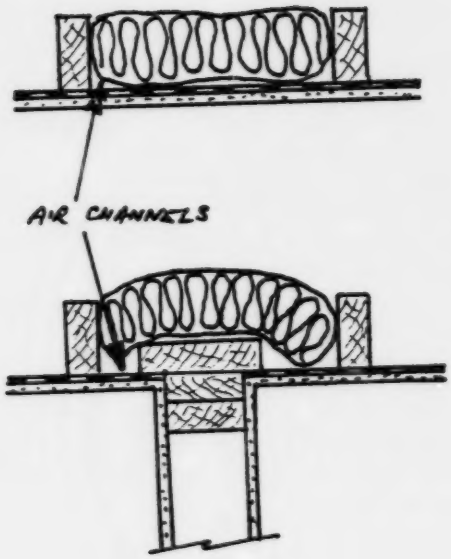
Caulk was applied around the sink drain pipe, where it passed through the drywall and connected into the vent stack.

The milk chute was provided with foam weatherstrip and good quality latches, to ensure a reasonably airtight fit when the two small doors were closed. It was necessary to install plywood backing strips as a base for the weatherstrip. Details are shown in the sketches below.



6.1 Assessment

The roof had a low pitch and the trusses were built with large plywood gussets. It was therefore difficult to move around the attic (see sectional drawing in figure 1). The condition was generally good; the frames, sheathing, shingles and flashing were acceptable and required no rehabilitation.



The insulation consisted of paper-backed mineral wool batt, about 90 mm thick and with an estimated thermal resistance of RSI 1.59. This type of insulation does not have good square edges, and as a result there may be small air channels running along the corners between the ceiling trusses and the drywall. These air channels may be even larger when the nailing strip of a partition wall runs parallel to the trusses, lifting the batt so that it makes poor contact with the ceiling. Under wind action, cold air can flow along these channels, thus reducing the effectiveness of the insulation. Since the insulation was about level with the tops of the ceiling joists, these joists displayed a strong thermal bridging effect (high thermal conduction through the wood, which is a relatively poor insulator). Some indication of this effect was visible on the ceiling, seen from below. The ceiling had not been painted for several years and there was some build-up of dust and slight discolouration. This discolouration was slightly more pronounced around the joist positions near the exterior walls, and the joist positions could be located quite accurately from the discolouration patterns.

The ceiling vapour barrier consisted of 0.05 mm polyethylene sheet, installed according to standard practices of the mid-1960's. There was a typical range of air leakage openings in the vapour barrier, including:

- Large gaps around the firestop of the prefabricated metal chimney.
- Gaps around two vent stacks, where they passed through the top plates of the partition walls.

- Gaps around electrical fixtures in the ceiling.
- Gaps along the tops of partition walls and exterior walls, where the vapour barrier had been terminated.
- A poorly sealed attic hatch, with gaps around the outside of the frame and around the hatch itself.

In spite of these several air leakage openings, there was no sign of moisture damage in the attic - such as might have occurred due to exfiltration of moist house air into the attic, through the various air leakage openings. The absence of moisture damage was attributed to the adequate ventilation of the attic space. The soffits were vented at each end, on the east and west sides of the house. In addition, the attic had a vent on the south gable wall and a roof louvre near the north-east corner of the roof. Ventilation passages from the soffit into the attic space were unblocked.

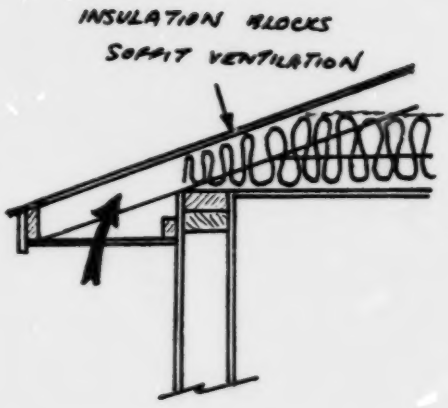
6.2 Retrofit Alternatives

There were two obvious ways of thermally upgrading this attic: the addition of more insulation and the sealing of all air leakage openings.

It was proposed to use this house to demonstrate medium-level retrofit techniques, and it was therefore appropriate to consider a medium level of attic insulation. In the Prince Albert Conservahome, which was a high-level retrofit exercise, the attic insulation level was increased to RSI 8.5. In the Yorkton Conservahome it was proposed to increase the insulation level to about RSI 5.3.

With this level of insulation the attic space would operate at a significantly lower temperature, and this might increase the risk of moisture accumulation in the attic. Therefore, as a pre-requisite to insulating the attic, it was considered to be essential to seal the various air leakage openings in the ceiling, as described in the brochure "Seal your House Before Re-Insulating", published by the Saskatchewan Science Council.

6.3 Factors affecting the choice



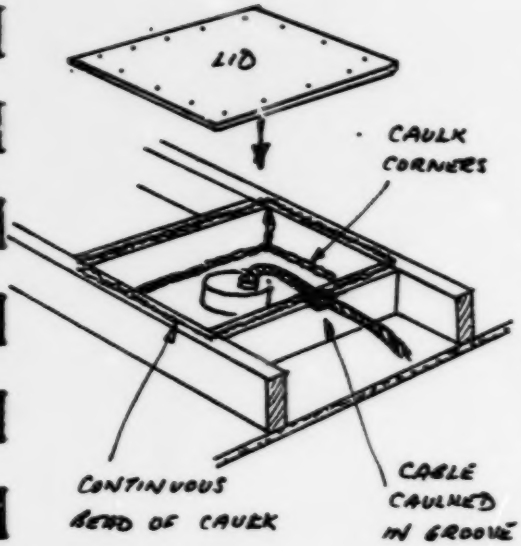
In this attic, one of the main features was the low roof slope. As a consequence there was little clearance between the roof and the ceiling at the eaves. From discolouration patterns and thermographic scans it was known that thermal bridging was causing fairly large heat losses at the tops of the exterior walls. One way to reduce these heat losses is to pile insulation on top of the exterior walls, but in this instance the low roof slope meant that the insulation would block the ventilation air flow from the soffits. This is an advantage from the point of view of thermal efficiency, since it reduces the ventilation cooling effect at the top of the exterior walls. At the same time, however, it also reduces the general rate of ventilation through the attic space. This ventilation may be reduced to a level below the requirements of the building code, and may lead to moisture accumulation in the attic.

By sealing the various air leakage openings at ceiling level, the rate of moisture movement into the attic is reduced, and lower ventilation rates become tolerable. The sealing work therefore makes it possible to pile insulation at the eaves, even though it may inhibit the soffit ventilation process. It was therefore decided to instruct the contractor to pile insulation against the eaves.

There are two ways of dealing with a leaky attic hatch: one is to relocate the hatch on the attic gable wall, where it does not penetrate the vapour barrier envelope of the house; the second way is to provide the hatch with suitable insulation and airtight seals. The first method is more expensive and was demonstrated on the Prince Albert Conservahome. The second way is more in keeping with a medium-level retrofit, and was therefore chosen for this house.

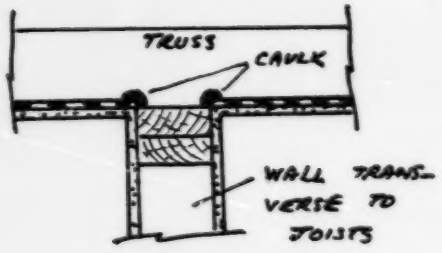
6.4 Details of the upgrading work

Sealing:

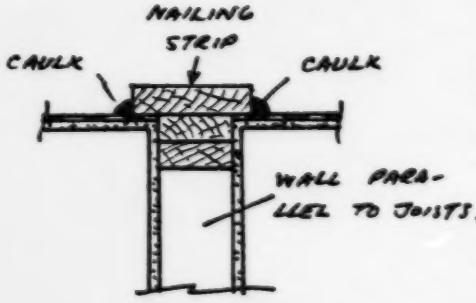


The existing insulation was lifted and stored at various places around the attic, where it would not get in the way of sealing work.

All ceiling electrical fixtures were located. Blocking was installed between the ceiling joists, to make a square frame around each fixture. The inside corners of this frame were caulked, to make airtight joints. Grooves were cut in the top of the frame to take the electrical cables. These were then fixed in the grooves and caulked. A continuous bead of caulk was run around the top of the frame, and a plywood top was nailed in place, to make an airtight box around the fixture.



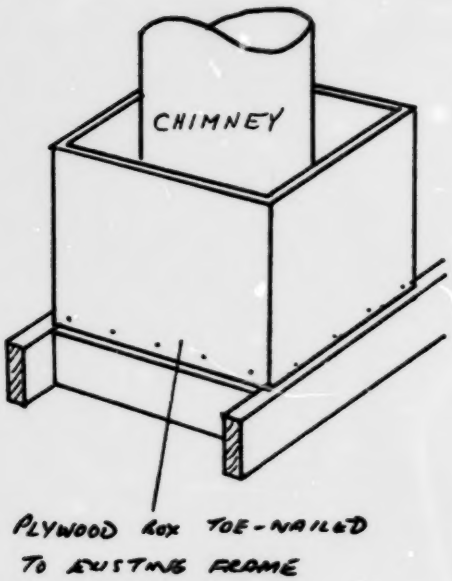
At the top of the partition walls, caulk was applied in the gap between the wood frame and the vapour barrier, to make an airtight seal. Partition walls ran both parallel and transversely to the ceiling joists. The two wall types have a different method of construction at the top and require slightly different caulking techniques, as shown in the sketches. Ideally, this work should be conducted along the tops of all partition walls and exterior walls, but because of the low eaves it was practically impossible to work around some parts of the attic perimeter.

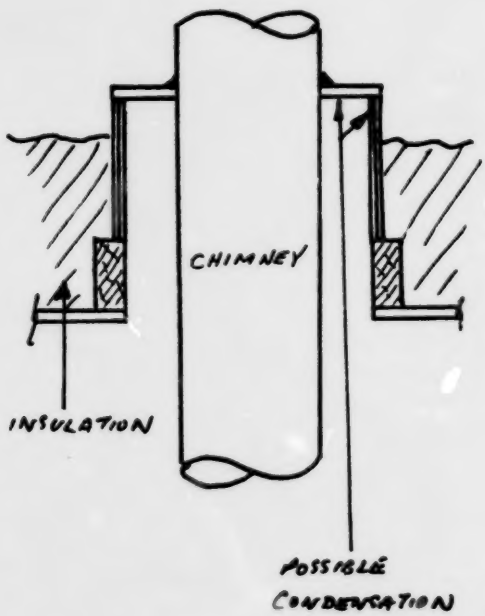


Cable openings, cracks and large knot holes were located in the top plates of the partition walls, and were filled with caulk. Oakum packing was worked into the gaps around the two vent stacks, to make a reasonably airtight seal that would allow some vertical expansion and contraction of the stacks.

Chimney sealing:

A four-sided box of 12 mm plywood was constructed around the chimney. The box was at least 50 mm clear of the chimney, to conform with safety regulations that require more than 50 mm clearance between the





prefabricated metal chimney and combustible materials. The top of the box was 300 mm clear of the top of the ceiling joists to prevent insulation from coming into contact with the chimney.

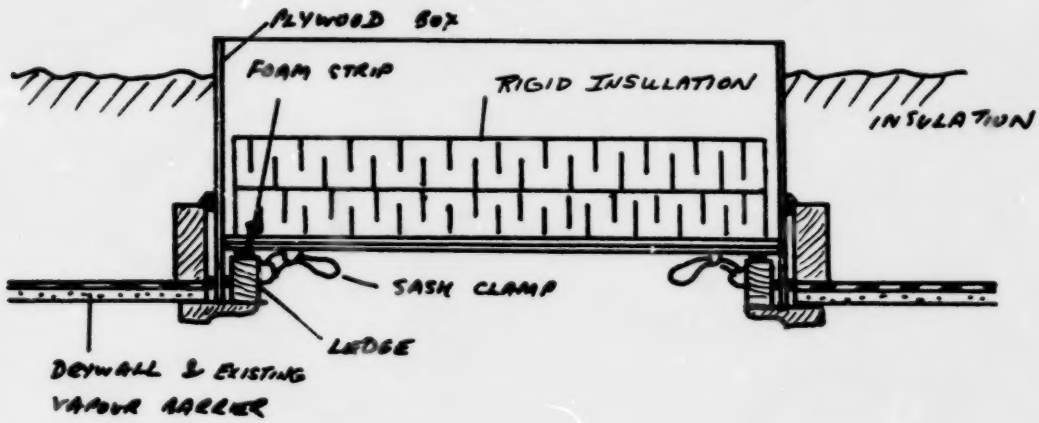
In building such an enclosure around a chimney, it is difficult to decide whether to close off the top of the box or leave it open. If the box is closed off, with a non-combustible plate of asbestos-cement board, then this becomes part of the air-vapour barrier envelope of the house. Since it is not insulated, there is a possibility that condensation may occur on the underside of the plate. Some people therefore favour the use of a fire-resistant insulation at this point - such as pumice block. Others feel that enough heat will rise from the flue to maintain the top plate above the dewpoint condition. Opinions differ and the problem has not been thoroughly investigated. The other alternative is to leave the top of the box open. In normal construction this is not advisable, since the firestop usually has large gaps around it, and there will be a considerable leakage of humid air through the top of the box. However, in this case it was proposed to build an airtight enclosure around the furnace, which would require sealing around the chimney at the level of the basement ceiling. Some air leakage can still occur through the framed enclosure around the chimney, but this is not usually very large.

Accordingly, it was decided to leave the top of the box construction open.

Attic hatch:

The existing hatch cover and trim were removed. Caulking was applied around the inside of the hatch frame, to make as good a seal as possible to the existing vapour barrier. A four-sided plywood box was then constructed inside the hatch frame, high enough to serve as an insulation stop for the increased level of insulation. The outside of the box, and the corners, were caulked to make airtight seals. A new ledge was installed around the bottom of the box, to support the hatch. A continuous foam weatherstrip was attached to the top of the ledge. The hatch cover was cut to fit

the new opening. Two layers of 50 mm extruded polystyrene rigid insulation were attached to the top of the cover with adhesive, and the cover was then installed. Sash clamps were fitted to the cover, to pull it down tightly onto the weatherstripping.



Insulation:

The existing batts were replaced carefully, to give a good fit between joists and minimise the possibility of air channels under the batts. Loose fill insulation was blown into the attic, to give a total thermal resistance of RSI 5.3. The contractor was told to install the new insulation right up to the eaves, and was given the option of using cellulose fibre or blown glass fibre. Since the risk of moisture damage was judged to be minimal, both types of insulation were acceptable in this case.

7.1 Assessment

The doors consisted of solid core wood units with wood storm units. Their condition was good, though they needed sanding and a new coat of paint throughout. The main doors had been fitted with good quality weatherstripping, but the weatherstripping showed extensive deterioration due to age and had lost most of its sealing capabilities. None of the doors had warped significantly. The south-facing door had window inserts in both the main and storm units, and was contributing to the solar heat gain of the house.

The living room picture window consisted of three identical sections of double glazing, fixed and sealed in a wood frame. The gap between panes was estimated to be 12 mm or less.

All the remaining windows on the main storey consisted of the same basic design: a square unit with wood frame. Each unit had a fixed-sealed single pane of glass on the inside, and a clip-on aluminum framed single pane on the outside. The sealing around the aluminum clip-on was moderately good, and the gap between the two panes was less than 12 mm.

The master bedroom and kitchen contained double units of the above type - one being a fixed-sealed unit and the other being an awning type. The bathroom and the two remaining bedrooms had single units, of awning type.

Signs of excessive condensation were found on most of the windows, but particularly the bathroom window. All frames needed sanding and a new coat of paint.

Each awning unit - five altogether - was provided with two sash clamps and a butt-type copper sealing strip, which was compressed against the awning sash in the closed position. The sash clamps had worn loose in most cases and there was some free play on the awnings in the closed position. Also, the copper seals had lost most of their resilience and effectiveness.

The basement had three windows along the east wall. These were wood-framed awning types, with one fixed-sealed pane and one clip-on aluminum storm pane. The windows were held shut by sash adjusters, which usually exert a strong closing force on the sash, and give a high level of airtightness provided that the seals are in good condition. In this instance the seals were poor and the windows leaky.

7.2 Retrofit Alternatives

Windows are usually a major source of heat loss from a house, both by thermal transmission and by air leakage around the openable sections. The retrofit options are therefore directed at each of these mechanisms of heat loss, and may consist of upgrading the thermal resistance of the window units or improving the window seals.

The condensation damage around the windows was a clue to their main defect. Excessive condensation on windows is an indication either of poor thermal resistance or of excessive humidity levels in the house. In this instance, the structural details of the windows suggested that the condensation had been caused by poor thermal resistance. The windows had a gap of less than 12 mm between panes. The highest thermal resistance usually occurs when the gap between panes is about 19 mm. The thermal resistance decreases progressively as the gap is reduced, and these windows were therefore suffering from too narrow a gap between panes. In addition, the outer pane was a clip-on storm (in all but the double-glazed units in the living room). The seals on these may have been ineffective, and there may have been some air flow between the inner and outer panes, which would further reduce the effective thermal resistance of the window units. It is difficult to prove that this is happening in a site assessment, but all the clues were consistent with this interpretation.

The windows were believed to be reasonably airtight at the sash seals. However, the design of the awning

units was such that the airtightness could be increased at very low cost.

Accordingly, it was decided that the window retrofit in this house should be directed mainly at upgrading the thermal resistance of the windows, with some attention to sealing - as a secondary measure.

7.3 Factors affecting the choice

Of the six Conservahomes, the Yorkton one was the last to be purchased and the last to go through the retrofit design process. It was therefore seen as an opportunity to demonstrate some window retrofit options that had not been covered in the other Conservahomes. The Conservahomes at Maidstone, Weyburn and Swift Current were fitted mainly with double-hung sash units with storm windows. These were dealt with in various ways. The Prince Albert Conservahome was fitted with aluminum sliders of fairly recent design, and these were replaced with units of higher quality. The Moose Jaw Conservahome was fitted with wood-framed fixed-awning windows, but the retrofit work on that house was restricted to low-cost options. In these five houses there was no demonstration of medium-cost retrofit on windows of modern design. The windows on the Yorkton house were ideally suited to such an approach, and this was consistent with the medium-level retrofit objectives of this house. It was therefore decided to demonstrate a range of medium-cost retrofit options on the windows.

The large fixed-sealed units in the living room were a major source of heat loss. It was decided to upgrade these by converting them to quadruple-glazed units. This would increase their thermal resistance substantially, and would also give some slight benefit by reducing the glare of the setting sun (when living room windows face westwards, the evening sun is often troublesome in winter and summer).

There were two other fixed-sealed units on the main floor: one in the kitchen and one in the master bedroom. It was proposed to convert these to triple-glazed units.

It would also have been desirable to convert the five awning units to triple-glazed designs, but this could not have been done without major structural modifications. It was therefore decided to retain these as double-glazed units and to concentrate on improving the sash seals and the effectiveness of the storm panes.

A different strategy was adopted for the awning window in the bathroom. The condensation damage on this window was more severe than on others, in spite of the ventilation system in the bathroom. It was therefore decided to convert this window to a triple-glazed design. To do this, it would be necessary to remove the awning facilities and convert the window to a fixed-sealed unit. This would eliminate the use of the window as a ventilation system. The existing bathroom fan was considered to be adequate for ventilation purposes, and, together with the upgraded thermal resistance of the window, would minimise condensation damage.

Of the three basement windows, it was decided to convert two to fixed-sealed, triple-glazed units. The remaining window was to be blocked-in, and used as a panel for the installation of vents for the new ventilation system.

The doors were considered to be adequate, and the upgrading was to be limited to simple rehabilitation together with replacement of the seals.

7.4 Details of the upgrading work

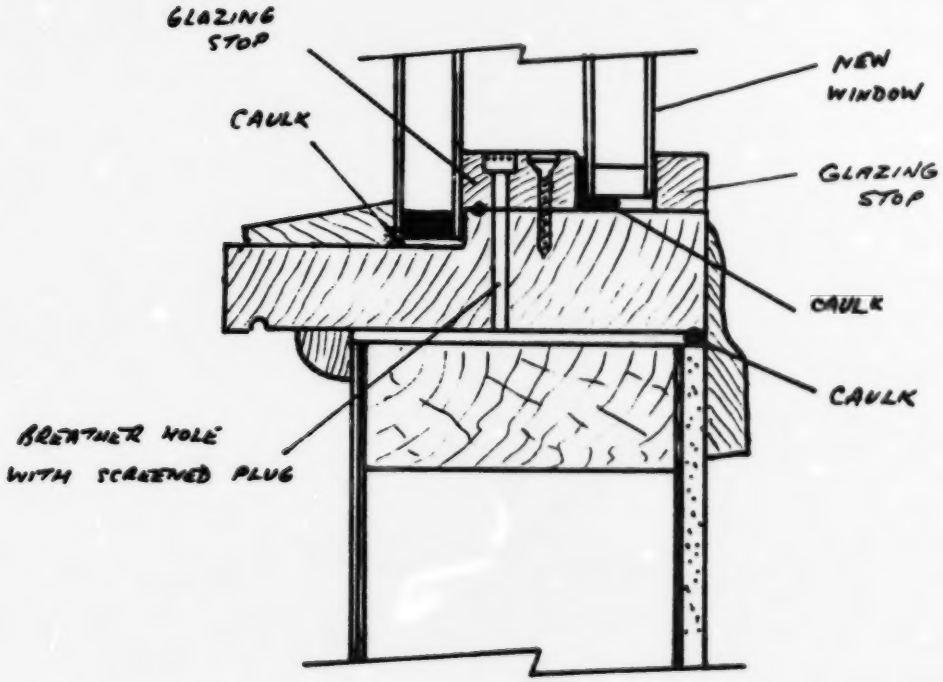
Living room window:

The trim on the exterior of the windows was removed and caulk was applied around the sash frames to

improve the seal. The trim was then replaced. New glazing stops, of 20 mm x 38 mm clear fir, were installed on the interior of the windows, and were caulked and screwed to the existing frame. Breather holes were drilled through the glazing stops and existing frame, at the head and sill. These were then fitted with screened plugs. The purpose of this feature was to provide an opening for the dissipation of any moisture that might build up between the panes. Note that the gap between the window frame and the main stud frame had been sealed previously, as part of the general sealing work on the exterior walls. Therefore the breathing holes were coupled to the dry exterior air rather than the moist house air.

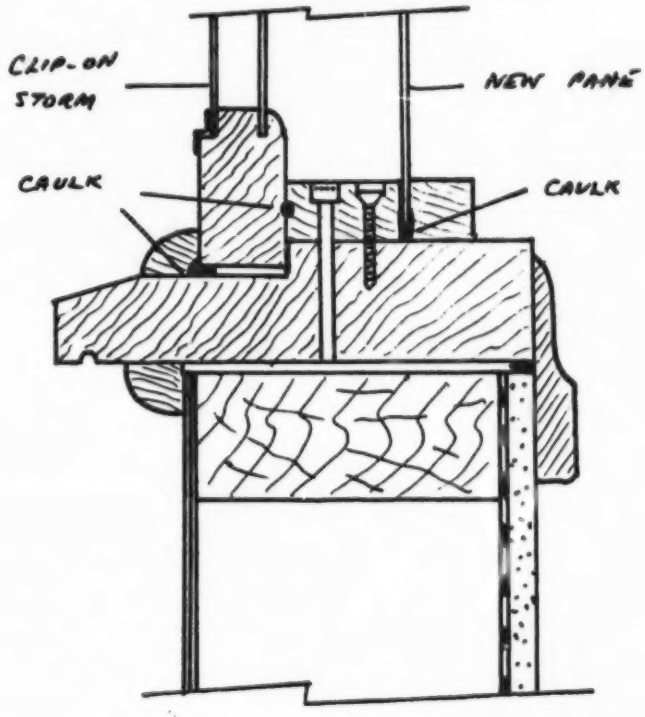
At this stage all the existing and new wood was repaired, filled, sanded and painted.

New double-glazed windows were installed against the glazing stops. These were set in caulk, to give an airtight seal, and then were fixed in place with a strip of glazing stop.



Fixed-sealed window sections in bedroom and kitchen:

These were converted to triple-glazed units using the same techniques as in the living room windows. The details are shown in the following sketch:



Bathroom window:

The awning hardware and weatherstripping were removed, and all holes were filled and sanded. The window was then caulked and screwed into place, converting it to a fixed-sealed unit. An extra pane of glass was then installed on the inside, following the details given in the sketch above.

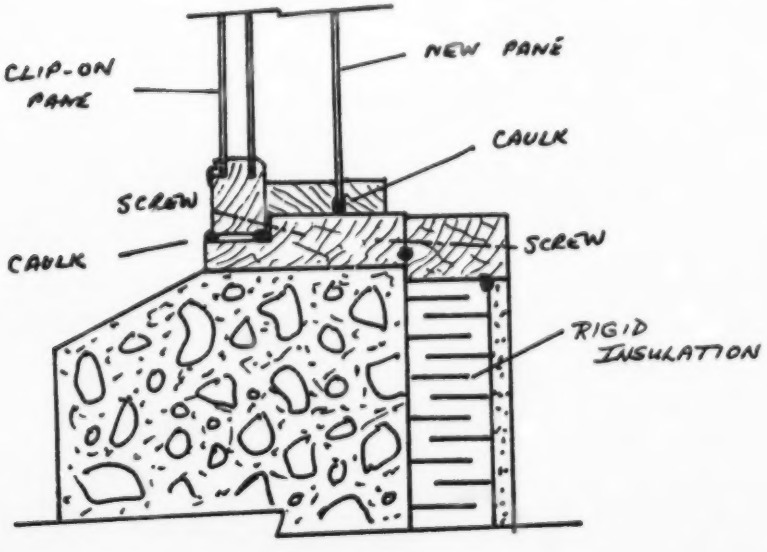
Storm windows:

The clip-on aluminum-framed storm windows and their hardware were removed from the windows in the kitchen, bathroom and bedrooms. The wood frame exteriors were repaired, sanded and painted. The storm windows were then re-installed, and were provided with thin seals in the form of foam weatherstrip.

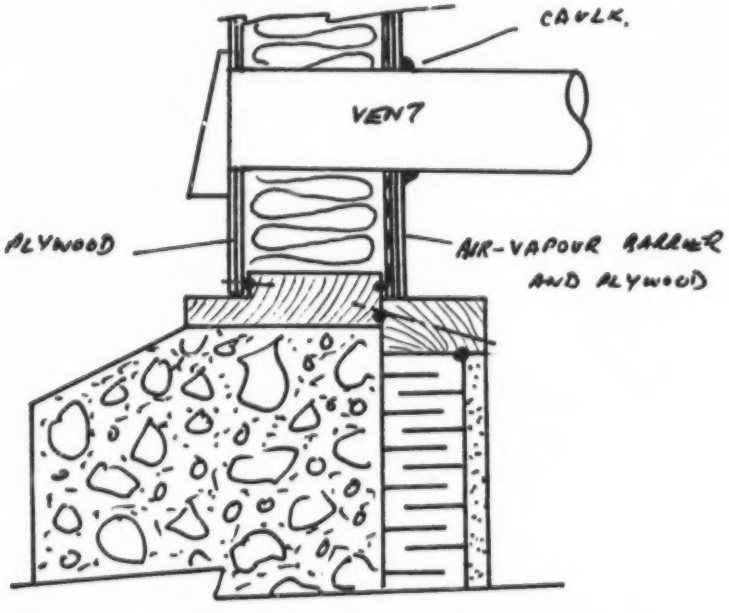
Basement windows:

Two of the windows were retained, and the third was blocked-in for use as a panel for ventilation ports.

The retained windows were treated in the same way as the main storey windows. The awning hardware was removed, the sashes were repaired and then caulked and screwed into the frames to make fixed-sealed units. Glazing stops were installed on the interior, which was then painted. A new interior pane was installed, caulked around the edges and fixed in place with further sections of glazing stop. Finally, the exterior storm was removed, the exterior woodwork was repaired, sanded and painted, then the storm was re-installed with sealing strip. The details are shown in the following sketch:



On the blocked-in window, the existing window sash was removed, and a sheet of 12 mm plywood was caulked and nailed to the exterior of the frame. Two vents, 100 mm diameter, were then installed through the plywood. The window cavity was insulated with glass fibre batt, and a layer of 0.150 mm polyethylene was then caulked and stapled to the interior face of the frame. An interior section of 12 mm plywood was then fitted to the frame, around the two vents. Finally, caulking was applied around the vents where they passed through the plywood. The details are shown in the following sketch.



Doors:

The existing weatherstripping was removed. The door units were repaired, sanded and painted. New weatherstripping, of good quality, was installed around the main door units. The storm doors were left unsealed to allow easy closing.

8.1 Assessment

The furnace was a forced-air natural gas unit with an input capacity of 32.8 kW (112,000 Btu/h). It was in good condition and its measured thermal efficiency was 73.8%. This was unusually high for a furnace of this type, and warranted further investigation. The cause was traced to the ventilation air duct, which was coupled to the cold-return plenum of the furnace. This was bringing cold fresh air into the return air side of the furnace and was thereby lowering the temperature of the return air. As a result, the heat transfer from the furnace to the return air was improved, making the furnace more efficient than normal.

The water heater was a 151.5 litre unit, with an input rating of 10.54 kW (36,000 Btu/h). It was in good condition.

No major defects were identified in the ducting.

8.2 Retrofit Alternatives

The furnace and domestic hot water heater were in good condition with several years of useful life left. There was therefore no justification for replacing them as a rehabilitation measure. This being so, it would not have been cost effective to replace them with more efficient units - as an energy conservation measure.

It was therefore decided to overhaul and tune the furnace, and to do nothing to the domestic hot water heater.

8.3 Details of the upgrading work

The furnace was first given a general overhaul, consisting of the following work:

- The heat exchanger was checked, and any scale and rust were removed.
- The contractor was asked to inspect the fan and clean the blades, if dirty.
- The fan and motor bearings were oiled.
- The pulley belt was adjusted for correct tightness.
- A new filter was installed.

The furnace was then tuned by adjusting the burner air supply to give maximum thermal efficiency, as measured with a furnace efficiency instrument.

In retrospect, the furnace upgrading work could have been more extensive without incurring any significantly greater costs. It might have been beneficial to inspect the gas nozzle sizes and replace them with the smallest available. This would downgrade the furnace capacity, bringing it more into line with the reduced heating requirements of the house.

9.1 Assessment

The house contained four ventilation ducts in the basement:

- An exhaust duct connected to the ceiling fan in the family room.
- An exhaust duct connected to the ceiling fan in the bathroom.
- A dryer exhaust duct.
- A fresh air inlet, connected to the return air plenum of the furnace.

The dryer exhaust was vented through a modified basement window, and the other three duct systems were connected to vents at the top of the east foundation wall.

It is unusual to find so many ventilation ducts in a house of this age. It is surmised that the owner had installed these ventilation systems to control the condensation on windows by lowering the relative humidity of the house air.

An inlet fresh air duct, connected to the return air plenum, is not uncommon in houses of more recent construction. Opinions vary on the advisability of such a system. The incoming fresh air helps to balance the action of the various exhaust systems around the house, and is a useful expedient in an airtight house, since it counteracts the depressurisation effects of the exhaust fans, which might induce furnace backdraft. It is doubtful that such a system was really necessary in this house, since there was an adequate supply of fresh air through natural infiltration.

Currently, there are no generally-accepted techniques for dealing with fresh air connections to return air plenums. If the furnace is allowed to operate in the normal way, cold fresh air will be drawn into the house by the action of the furnace fan. But when the fan is inactive, cold air will continue to flow into the plenum, due to a combination of pressure effects that normally exist

in the house. This cold air will tend to fall to the lowest point, and if the return air plenum has a register at some low point in the basement, there will be a steady flow of cold air out of this register. This is what was happening in the Yorkton house.

The alternative is to dilute the cold air by operating the furnace fan continuously - at low speed when the furnace is not delivering heat. This also has a disadvantage: it delivers cool air continuously through the various warm air outlets around the house, and may create zones of thermal discomfort.

9.2 Retrofit Alternatives

Special care is needed when retrofitting a house that shows extensive signs of condensation - as in this case. Before finalising the retrofit design it is essential to know what caused the condensation in the first place, since an improper retrofit might worsen the situation. In this instance the condensation damage was confined to the windows, and there were therefore three possible causes:

- Excessive moisture generation in the house, due to lifestyle patterns.
- Low levels of air change, due to tight construction and inadequate ventilation.
- Low thermal resistance of the window units.

From previous discussions it is clear that the second cause can be ruled out. The first cause was difficult to assess, since contact could not be made with the previous owner. It was assumed that since the owner had gone to such lengths to control humidity levels, he was aware of some of the causes and would have taken steps to control the rates of moisture generation in the house. The third cause of condensation - low thermal resistance of the windows - was consistent with the design of the windows, and was believed to be the main cause of condensation effects.

The retrofit design of the house relied most strongly on this interpretation of the causes of condensation damage. It followed that the condensation problems could be practically eliminated by the window upgrading techniques described in an earlier section. It also followed that the various sealing techniques could be pursued without risk of inducing serious condensation damage.

Airtightness tests were conducted on the house before the retrofit work. These gave an air leakage rate of 2.64 air changes per hour at a pressure differential of 50 Pascals. The house was therefore slightly better than average, for Saskatchewan. It was hoped that the sealing techniques would decrease the natural air change rate of the house to about 0.1 air changes per hour. Airtightness tests after the retrofit confirmed that something close to this level had been achieved. The test results gave an air change rate of 1.01 air changes per hour at 50 Pascals, making this the tightest retrofitted house in the project and placing it on the same level as energy-efficient houses of new construction.

Opinions differ on the required level of ventilation in a house; recommended levels range from 0.3 to 0.5 air changes per hour. Since it was hoped to reduce the natural infiltration level of the house to 0.1 acph, this meant that the house would have to be provided with a ventilation system with a capacity of at least 0.2 acph - about 77 m^3/h (45 cfm).

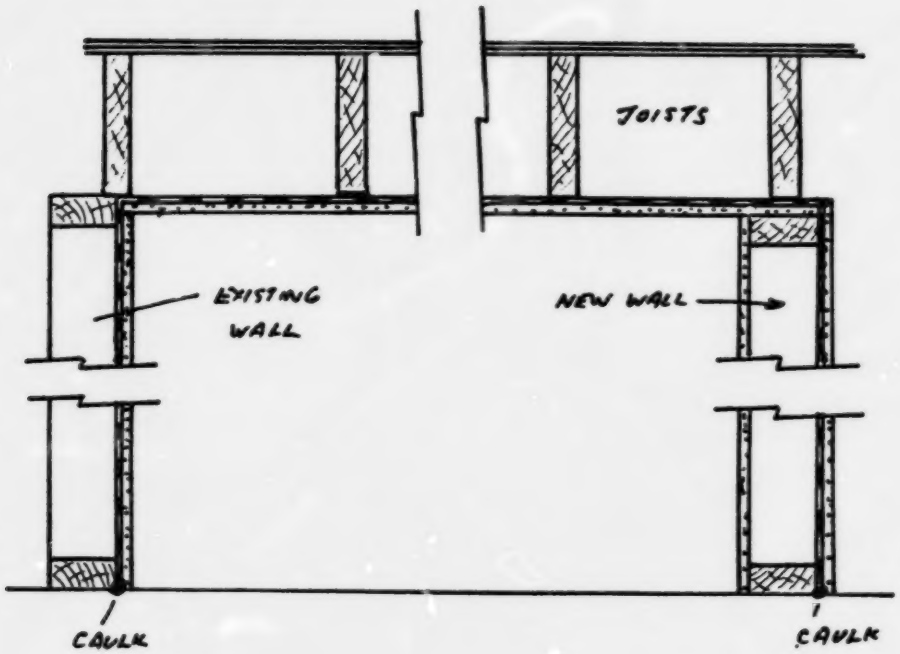
Ventilation is a source of heat loss, and at a rate of 77 m^3/h it was calculated that the ventilation system would contribute about 13% of the total heat losses of the retrofitted house. This could be reduced to about 4% by incorporating an air-to-air heat exchanger in the ventilation system. The incremental cost of the heat exchanger was large and the anticipated energy saving was small. Therefore, this was not a cost-effective option. However, it was decided to install a heat exchanger for demonstrational purposes. At that time, the retrofit

design had already been developed on the other five Conservahomes. Heat exchangers of Japanese manufacture had been used on three. It was therefore decided to demonstrate a heat exchanger manufactured in Saskatchewan.

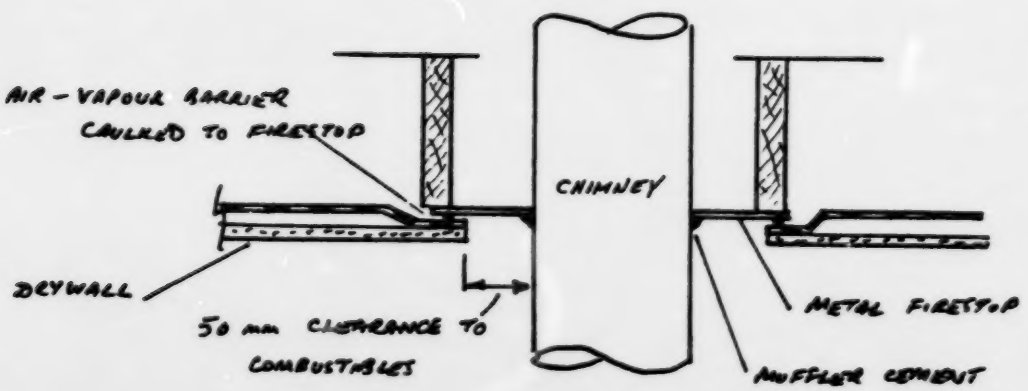
Combustion air supply is also a problem in an airtight house. There is a risk that the ventilation system will compete for air with the combustion and draft requirements of the furnace and domestic hot water heater. If this happens, the ventilation system may cause the combustion unit to backdraft, drawing combustion gases into the house air. A ventilation system does not constitute a proper air supply for combustion appliances - particularly if it contains complex equipment such as a heat exchanger. In an airtight house it is therefore desirable to provide the combustion appliances with their own fresh air supply. This can be done in two ways: either by ducting air to a point close to the appliances, or by building a reasonably airtight 'furnace room' around the appliances and providing a fresh air supply into this room. The authors favour the latter approach since it gives better separation of ventilation and combustion air requirements, and also has a number of safety advantages. It was therefore decided to construct a furnace room around the furnace and domestic hot water heater, including draft and combustion air supplies, sized according to the gas code requirements.

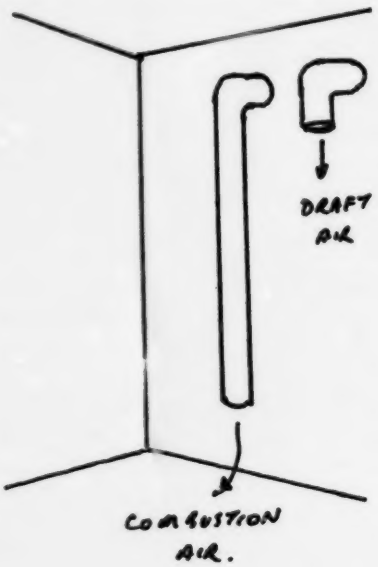
9.3 Details of the upgrading work

New partition walls were built in the basement, to make an enclosure around the furnace, and the domestic hot water heater. The layout of this new furnace room is shown in the basement plan in figure 1. The walls were provided with 0.150 mm polyethylene sheet, caulked and sealed to make an airtight enclosure. The walls were then covered with plasterboard. A hollow-core wood door was installed, and fitted with weatherstripping.



In an earlier section it was pointed out that, in the attic, the prefabricated metal chimney was surrounded by an open-topped box to hold back the insulation. This meant that air leakage could occur around the outside of the chimney, where it passed through the main storey ceiling. This air leakage was reduced considerably by constructing a sealed firestop around the chimney in the ceiling of the furnace room. The constructional details are shown below:





The existing fresh air duct to the return air plenum was disconnected, and a new duct was connected to the vent to serve as a combustion air supply for the combustion appliances. In accordance with the gas codes, this supply duct was terminated about 300 mm above the furnace room floor.

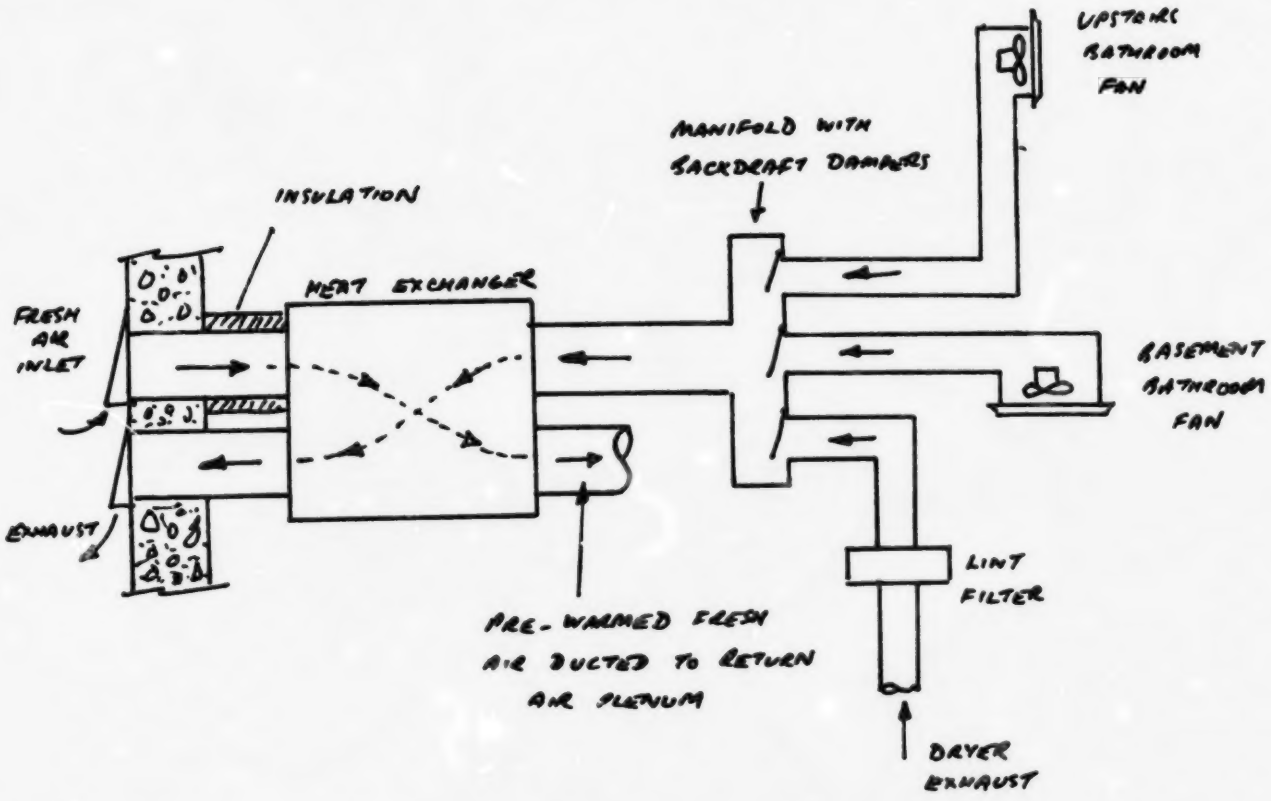
The existing exhaust duct from the ceiling fan in the family room was disconnected, and a new duct was connected to the vent to serve as a draft air supply for the combustion appliances. This duct was terminated about 1500 mm above the furnace room floor, in accordance with the gas code requirements.

An Enercon heat exchanger was installed on the east wall of the basement, outside the furnace room. The inlet and exhaust outlets were connected to the two vents that had been sealed and prepared as described in a previous section. A new vent was installed in the wall of the main-storey bathroom, and a duct connection was made into the basement. A new bathroom fan was installed.

Three stale air ducts were manifolded together and connected to the stale air inlet of the heat exchanger. These consisted of the ducts from the upstairs bathroom , the basement bathroom and the clothes dryer. The dryer duct was provided with a custom-made lint filter. Note that it is not always possible to connect a dryer to a heat exchanger; the exchanger may not have adequate flow capacity or the materials may not be able to withstand the high temperatures of the dryer exhaust. The heat exchanger used in the Yorkton house was suitable for dryer exhausting.

The incoming fresh air, having been pre-warmed in the heat exchanger, was ducted to the return air plenum of the furnace.

The full heat exchanger and ventilation system is shown schematically on the following page.



SCHEMATIC OF VENTILATION SYSTEM.

General repairs were conducted in the upstairs bathroom. Moulding was replaced and painted. A new towel rack was installed. The medicine cabinet was painted.

Damaged drywall, caused by condensation on windows, was repaired and painted. Trim around doors and windows were repaired, sanded and painted.

Damaged parging on the exterior of the foundation wall was repaired and finished to match the existing surface. The eavestroughs and downspouts were painted, and splash-pads were installed under the downspouts.

A damaged porch light above the south door was replaced.

It should be noted that, after purchase of the house, the exterior sustained damage from two hail storms. Repairs were conducted on exterior surfaces, including shingles, paintwork, siding and flashing. These were not considered to be part of the main retrofit and rehabilitation work.

For details of costs, projected energy savings and conclusions about this project, the reader is referred to the Overview Report, which is the first in this series of reports.

For further details of the work, the materials and the techniques, the reader is referred to the following Appendix, which consists of the detailed specifications as given in the contract documents.